

Response to Telcordia Technologies Comments on AirCell Proposal

Prepared for



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1 Introduction

ATG services use spectrum in the 849-851 MHz and 894-896 MHz bands, with ground to air transmissions on the low band and air to ground transmissions on the high band. Currently, Verizon Airfone is the only service provider utilizing the band, supporting narrowband transmissions (mainly voice) based on 6 kHz channels.

Recent efforts have concentrated on providing broadband services and promoting effective competition between service providers. To this end, in [1], AirCell proposed that two providers share the ATG bands by reversing the duplexing for the second provider (that is, having the second provider's aircraft receive on the high band and transmit on the low band). *The concept of reverse duplexing (bidirectional allocation) is well known in satellite communications [2-6] where it is used to achieve high spectral efficiencies.* Subsequently, Verizon Airfone / Telcordia submitted an unsubstantiated analysis [7] attempting to demonstrate that such a scheme would result in a severe interference between systems of two providers and that it is not immune to transmissions by the Naval air search radar in the 902-928 MHz band. In [8], AirCell provided further detailed analysis and supporting simulation results proving that its original sharing proposal can even be extended to allow utilization of the ATG band by four service providers. Furthermore, in [9] AirCell submitted an analysis that clearly refutes the unsubstantiated claims made by Verizon Airfone/Telcordia. Very recently, Verizon Airfone/Telcordia attempted to address the issues raised by AirCell in [10].

This document addresses the aforementioned recent ex-parte [10] filed by Verizon on 8/16/2004 in WT Docket 03-103. First, we provide a summary of the responses to [10], and subsequently provide a more detailed analysis. In short, we will demonstrate that Telcordia's claims are totally unsubstantiated.

2 Summary of Response to [10]

Nothing in Telcordia's rebuttal filings disproves AirCell's analysis on the basis of scientific evidence. Telcordia's arguments in [7,10] are based only on scenarios with clear misunderstandings, astronomically small odds, or unsubstantiated claims. For example:

- Telcordia cites AirCell measurements of ***Air-to-Air*** (ATA) path loss using “***belly mounted antennas***” in order to support its claim that the 10 dB system implementation margin is necessary in an ***Air to Ground*** (ATG) transmission scenario. The flaw of such a generalization is obvious, since ATG transmission does not suffer from the aircraft shielding/obstruction losses inherent to ATA scenarios with aircraft flying at different altitudes. In ATA link, the antennas are mounted on the aircraft belly. Therefore, the body of the lower altitude aircraft will prevent a clear line of sight between antennas when aircraft are near each other (as was the case in AirCell tests). As a result, on the ATA link there is always an additional loss beyond that of free space. However, Telcordia suggests that the same characteristics should be expected on the path between a belly mounted antenna and ground stations, where line of sight conditions clearly exist.

- In supporting the claims regarding the need for a 10 dB system margin for the ATG transmission channel, Telcordia does not provide a shred of channel measurement data or any other evidence and relies only on “Private Communications” with Airfone. Further, some implementation margin factors cited are characteristic of design margins, not implementation margins, and some of the factors are already explicitly accounted for in AirCell’s link budgets.
- AirCell measurements of ATA transmission further show that the potential for air-to-air interference is at least 10 dB smaller than that claimed by Telcordia. Interestingly, it seems that Telcordia implicitly agrees with ATA path loss measurements reported by AirCell in [8], while at the same time fabricating ATA interference scenarios with astronomically small odds that are based on assumptions ignoring the results of these measurements [7]. Thus Telcordia is clearly contradicting itself in the interference analyses presented in [7,10].
- Telcordia claims that AirCell’s original proposal ignores base-to-base station interference and that the base-to-base interference is a substantial problem. On the contrary, AirCell initially stated that base-to-base interference is controlled through proper spacing of the base stations and by using uptilted antennas. AirCell confirms that the results originally presented in [1,8] are correct and that the base-to-base interference can be engineered to be negligible. Furthermore, we will show in this document that the examples made by Telcordia/Airfone are completely unrealistic.
- Telcordia claims that AirCell’s reverse duplexed system would suffer debilitating interference from the Naval air search radar in the 902-928 MHz band. Telcordia fails to consider all the points raised by AirCell that demonstrate the low probability of this interference and the almost similar effects of this interference has in the current duplexing scheme and the reverse-duplexing scheme. Telcordia also fails to present either a probabilistic analysis (given the low odds of the underlying effects), or any data to support its claims. In this light, Telcordia’s claims are totally unsubstantiated.
- Telcordia objects to the fact that AirCell’s proposal would require 200mW transmission power from the aircraft. However, it is very well known that CDMA systems are interference limited and no gain is achieved by increasing the transmission power beyond a certain level.
- AirCell’s analysis demonstrated that two cross-duplexed systems planned according to AirCell’s proposal [1] do not interfere with each other. Based on the data rates used in the interference analysis, Telcordia claims that AirCell’s proposed method does not provide broadband services. The attempts to characterize the two-licensee and four-licensee AirCell proposals as anything different from broadband are **completely misleading**. AirCell’s prior submissions to FCC included simulating traffic conditions (NOT limits), of approximately 48 kbps from each aircraft. This was used as an example to demonstrate isolation between licensees/systems. To reference such parameter as the data rate capacity of a system under AirCell proposal and to reference the theoretical maximum of 1xEvDO technology as Airfone’s data rate capacity (hence “broadband”

offering) can only be considered a frivolous argument. In fact, it is common engineering knowledge that by choosing smaller cell sizes, it is possible to achieve the top speeds of 1xEvDO systems, both for Rev 0 and Rev A. More notably, any single service provider model cannot provide higher reverse link data rates given the cell sizes, the loading, and the air interface technology considered in AirCell's simulations. In fact, Telcordia does not provide any simulations or any other evidence to show that, when using similar broadband air interface technologies, a single licensed service provider can provide higher data rates than each of the multiple service providers of AirCell's proposal.

- Telcordia seems to be unaware of the existence of cross-duplexed (bi-directionally assigned) systems in satellite communications [2-6] and categorically rejects cross-duplexing.
- Regarding AirCell's four service provider model [8], Telcordia claims that any isolation gained by cross polarization will be significantly overwhelmed by other variables but does not provide any supporting data/simulations to support that claim.

In summary, nothing in the Verizon Airfone/Telcordia filings shows that AirCell's proposals will not provide two or more effective broadband ATG competitors, nor do they demonstrate that there is any substantial advantage under a single service provider model.

3 Detailed Response to [10]

3.1 *Comments on ATG Channel and Additional Link Margin Introduced by Telcordia:*

In [10], Telcordia continues to insist on its claim that a 10 dB additional link margin is needed to account for "antenna mounting accuracy, higher than expected cable loss, fading due to blockage, and other unexpected design losses" in a Ground to Air transmission scenario. This claim is based on "Private communications with Verizon Airfone".

As usual, Telcordia does not provide any evidence or channel measurement data to back up the claim.

- AirCell's experience [11] clearly demonstrates that the ATG wireless channels can be modeled as the line-of-sight and do not suffer from Rayleigh fading. Therefore, the ATG wireless channel is virtually Gaussian with the path loss exponent of the free space.
- Channel measurement results [12] clearly indicate that there are no losses due to blockage/shadowing in the ATG scenarios. The base station antennas are mounted above the neighboring blocking objects, and uptilted to eliminate specular reflections.
- There is no need to account for additional cable losses. A conservative cable loss value of 3dB is used in all AirCell's computation. Note that even in terrestrial cellular networks (where fading, shadowing and blockage are very common, the entire system

implementation link margin is 10 dB including cable and diplexer losses [13]). It is not clear how Telcordia accounts for a 10 dB system implementation link margin in addition to a total of 5 dB cable and diplexer losses in a good propagation environment such as ATG!

- The potential loss due to antenna mounting inaccuracy is extremely small given the beamwidth of the antennas. A 1 dB link budget margin to cover the potential losses due to antenna mounting accuracy and other losses might be appropriate, but the losses would be a worst-case loss, rather than the average loss expected on implementation.

Telcordia then cites AirCell measurements of ATA path loss in order to support its claim that the 10 dB system implementation margin is necessary in an ATG transmission scenario. Again, the error in such a generalization is obvious, since ATG transmission does not suffer from the obstruction losses inherent in ATA scenarios with belly-mounted antennas and aircraft at different altitudes. The body of the lower-altitude aircraft will *always* prevent a clear line of sight between antennas when the aircraft are relatively close. As a result, on the ATA link there is always an additional loss beyond that of free space. On the other hand ATG links are designed to have a clear line of sight (LOS). Therefore, it is *not* “reasonable to expect that there would be similar variations due to similar factors.”

In supporting its position regarding the ATG transmission channel, Telcordia does not provide a shred of channel measurement data or any other evidence. Thus, Telcordia’s claim for generalization of ATA path loss measurements between two aircraft with belly mounted antennas to the ATG path loss must be regarded as entirely incorrect.

3.2 Comments on Base-to-Base Interference Issues Raised by Telcordia:

In [7], Telcordia responded to AirCell’s proposal [1] by arguing that the base-to-base interference is a major issue. In [9], AirCell responded to Telcordia’s comments arguing that base-to-base interference of cross duplexed systems could be meager given terrain screening/obstruction losses, and considering the impact of the discrimination provided against the horizon with uptilted antennas. In [8], AirCell provides analysis proving that the system can be engineered so that this interference is negligible. The LOS propagation is assumed, once again to present a very conservative scenario and as an illustration for calculations.

In response to AirCell analysis, in [8], Telcordia provides an example, with an aircraft flying at an altitude of 1000 feet 12.5 miles away from the airport. It then claims that “neglecting the curvature of the earth, this corresponds to an elevation angle of less than 1° above the horizon, and that the antenna elevation gain must roll off by 25 dB within an elevation angle change of 1°.

The flaw in the argument made by Telcordia is obvious. Clearly an aircraft flying at an altitude of 1000 ft is either arriving or departing and is not 12.5 miles away from the airport! Under more realistic circumstances, selection of site locations and antenna patterns will allow coverage to be maintained while the base to base isolations are kept at negligible levels.

In short, AirCell analysis confirms that the results presented in [1,8] are correct and the base-to-base interference can be engineered to be negligible as originally claimed.

3.3 **Comments on The Impact of the AN/SPS-49 Naval Air Search Radar**

In [7], Telcordia claims that the transmission from the AN/SPS-49 Air Search Radar used aboard Naval warships poses a great interference threat to a cross-duplexed ATG system. ***Telcordia bases its claims on Airfone's experience and does not provide any hard evidence.*** In [9], AirCell argued that that interference probability is low, because "Air search radar is typically pointed towards sea. Additionally, ships typically turn off their AN/SPS-49 radar about 200 nm from the shore." Telcordia fails to present any data for interference levels seen at an aircraft today and it fails to provide concrete data and explain why Airfone's base stations do not regularly experience radar interference if its claims for propagation protection are true. Thus we maintain our position and challenge Airfone/Telcordia to back their claims with supporting data.

In summary, Telcordia claims that AirCell's reverse duplexed system would suffer debilitating interference from the Naval air search radar in the 902-928 MHz band. Since Telcordia fails to consider and present either a probabilistic analysis (given the low odds of the underlying effects) or a shred of data to support its claims, it is clear that Telcordia's claims must be regarded as totally unsubstantiated.

3.4 **Comments on Aircraft Transmit Power and Technology Evolution**

In [7], Telcordia objects to the fact that AirCell's proposal would require aircraft transmit power on the order of 200 mW. However, as it was pointed out in [9], it is very well known that CDMA systems are interference limited and no gain is achieved by increasing the transmit power beyond a certain level. The power level of 200mW (23dBm) is accepted in terrestrial 1xEvDO application as the value that balances forward and reverse communication paths.

Telcordia then argues that this power limitation makes it impossible to provide truly broadband services to airplanes. Telcordia cites AirCell's own results [1], which were presented to the commission solely to demonstrate that two cross-duplexed systems deployed according to AirCell's proposal [1] do not interfere with each other. **In fact, in the framework of AirCell's proposed system, by means of straightforward network engineering, it is possible to achieve greater capacity per aircraft and approach the maximum speeds of 1xEvDO systems.**

We note that *even Airfone's proposed one service provider model can not provide higher reverse link data rates given the cell sizes and the loading considered in AirCell's simulations.* In fact, Telcordia does not provide any simulations to substantiate that a truly broadband one service provider system can be designed that can provide higher data rates than those of AirCell's proposal under similar assumptions.

3.5 **Reverse Link Pole Point Formula**

In [7] Telcordia claims that AirCell uses an incorrect formula and that the derivation provided in the previous AirCell filing [9] omitted a couple of steps. The steps omitted in [9] are trivial algebraic manipulations that can be easily reconstructed. These steps were left out for the sake of brevity. To eliminate all doubts, this document presents full proof of equivalence of AirCell pole point calculations and the one presented by Telcordia's engineering team. For the sake of

completeness this document repeats some of the formulas already given in [9]. The equations omitted in [9] are given in italic font.

Telcordia's interpretation of quantities in equation (6, pg. 22) of AirCell's document [1] are incorrect. The factor I_{adj} in equation (6, pg. 22) is defined as the ratio of the out of cell interference to the in-cell interference. Using, Telcordia's notation, the proper expression for I_{adj} can be written as

$$I_{adj} = \frac{I_{oc}}{\sum_{j \neq i} P_j} \quad (1)$$

where I_{oc} is as defined on pg. 64 of Telcordia's document.

On the other hand, factor f in Telcordia's document is defined as

$$f = \frac{I_{oc}}{\sum_j P_j} \quad (2)$$

Therefore, contrary to Telcordia's interpretation, $f \neq I_{adj}$ and equation (29, pg. 66) of Telcordia's document [7] is incorrect.

However, the analysis of the pole point provided by Telcordia in [7] is accurate and essentially identical to AirCell's analysis. To demonstrate that this is the case, consider the following *equivalent* pairs of equations.

$$\text{Telcordia [7] (20, pg. 64)} \quad I_{tot} = N + (1 + f) \sum_j P_j \quad (3)$$

$$\text{AirCell [1] (6, pg. 22)} \quad I_{tot} = N + (1 + I_{adj}) \sum_{j \neq i} P_j + P_i \quad (4)$$

Assuming K identical mobiles

$$\text{Telcordia [7] (21, pg. 64)} \quad I_{tot} = N + (1 + f)KP \quad (5)$$

$$\text{AirCell (from 4)} \quad I_{tot} = N + (1 + I_{adj})(K - 1)P + P \quad (6)$$

Using $I_{tot} = (M + 1)P$ (see Telcordia [7] pg. 64), (5) and (6) transform into

$$\text{Telcordia} \quad (M + 1)P = N + K(1 + f)P \quad (7)$$

$$\text{AirCell} \quad (M + 1)P = N + (K - 1)(1 + I_{adj})P + P \quad (8)$$

When the system operates at high traffic loading, the thermal noise terms, N , in (7) and (8) can be neglected, and (7) and (8) reduce to

$$\text{Telcordia} \quad (M+1)P = K(1+f)P \quad (9)$$

$$\text{AirCell} \quad (M+1)P = (K-1)(1+I_{adj})P + P \quad (10)$$

From (9), the expression for pole point is derived as

$$\text{Telcordia [7] (23, pg. 65)} \quad K_{pole} = \frac{M+1}{1+f} \quad (11)$$

From (10) the expression for the pole point is derived as

$$K_{pole} - 1 = \frac{M}{1+I_{adj}} \quad (12)$$

and

$$\text{AirCell [1] (9, pg. 23)} \quad K_{pole} = 1 + \frac{M}{1+I_{adj}} \quad (13)$$

Therefore, the pole point formulation given by Telcordia is completely equivalent to the one provided by AirCell when the quantities are interpreted in a correct manner. Both (11) and (13) are used in technical literature and Telcordia's statement that formulation "(13) is not useful" is highly opinionated. The fact that someone is used to one of the two formulations does not necessarily render the other one as "not useful".

4 Analysis of Telcordia's Comments on AirCell's Four-System Proposal

In [1], AirCell proposed the use of duplex inversion to share the ATG bands between two independent service providers. In [8], AirCell proposes sharing of the bands among four providers using both duplex inversion and polarization isolation utilizing 12 dB of isolation provided by orthogonal polarizations. One pair of cross-duplexed systems would share each polarization (horizontal and vertical).

Telcordia makes a number of comments

- Telcordia states: "Unfortunately, [6] does not actually analyze or simulate a 4-system sharing scenario but rather simulates only a 2-system scenario, where the two systems are co-duplexed but cross-polarized. Any interaction or coupling among the two pairs of systems is ignored".

The interaction between systems is minimal. For the sake of clarity the results are presented just for pair of systems operating as co-duplexed and cross-polarized. AirCell

simulator simulates all four systems and it was used to determine that the coupling is essentially non-existent.

- Telcordia raises the issues of base-to-base interference again.

We have already commented on the base-to-base interference issues raised by Telcordia before (in the previous section) and we have shown this to be a non-issue in Section 3.2.

- Telcordia again raises the issue of service model and aircraft transmit powers.

We have addressed these issues in Section 3.4.

- Telcordia claims that any isolation gained by cross polarization will be significantly overwhelmed by other variables.

Again, Telcordia does not provide any supporting data/simulations to support their claim. In fact measurements performed by AirCell [12], clearly shows that 12 dB cross-polarization isolation is valid.

5 Conclusion

In conclusion, nothing in the prior [7] and the latest Verizon Airfone/Telcordia ex-parte [10] is substantiated, and

- Telcordia has failed to point out and subsequently substantiate any flaws in the AirCell two systems proposal in [1] and the AirCell four-system proposal in [8].
- Telcordia has been repeating its unsubstantiated claims many times without providing any evidence/data/simulations to back up its position.
- Telcordia has failed to support Airfone's claim to providing truly broadband systems under Airfone's proposed one service provider model using detailed simulations/data.

In contrast, AirCell has provided substantiated proposals, detailed simulations, and business studies proving that multiple service providers can co-exist and provide broadband services in the ATG band. AirCell's approach is clearly a technically viable approach that enables competition in the ATG broadband market.

6 References

- [1] Ivica Kostanic and Dan McKenna, "Evaluation of the ATG Spectrum Migration Concept," March 10, 2004, AirCell report to the FCC, WT Docket 03-103.
- [2] A.G. Reed and M.C.J. Posen, "Interference in the Fixed Satellite Service Bands Between the Feeder-Links of Networks Using Non-Geostationary Satellites and Networks Using Geostationary Satellites," Proceedings of the 3rd European Conference on Satellite Communications, November 1993.
- [3] H. Kobayashi, H. Shinanoga, N. Araki and Y. Ito, "Study on Interference Between the Non-GSO MSS Gateway Station and GSO FSS Earth Station Under Reverse Band Operation." Proceedings of the IEEE 10th International Conference on Digital Satellite Communications, May 1995.
- [4] ITU-R Recommendation 848, 1992, "Determination of the coordination area of a transmitting earth station using the same frequency band as receiving earth stations in bidirectionally allocated frequency bands".
- [5] ITU-R, Recommendation 847, 1992, "Determination of the coordination area of an earth station operating with a geostationary space station and using the same frequency band as a system in a terrestrial service".
- [6] ITU-R, Recommendation 849, 1992, "Determination of coordination area for earth stations operating with non-geostationary spacecraft in bands shared with terrestrial services".
- [7] Anthony A. Triolo and Jay E. Padgett, "Coexistence Analysis for Multiple Air-to-Ground Systems," June 3, 2004, Verizon Airfone report to the FCC, WT Docket 03-103.
- [8] Ivica Kostanic, "Evolution of the ATH Migration Concept (Part 2)," June 29, 2004, AirCell Report to FCC WT Docket 03-103.
- [9] V. Tarokh and A. Varadachari, "Response to Telcordia Technologies Comments on AirCell Proposal," June 17, 2004, AirCell report to the FCC, WT Docket 03-103.
- [10] Jay E. Padgett, "Response to Recent AirCell Filings and Summary Comments on AirCell Proposals", Telcordia Technologies, Inc., Applied Research, Wireless Systems and Networks, August 16, 2004, WT Docket 03-103.
- [11] Private Communications, AirCell Inc.
- [12] Proprietary Data, AirCell Inc.
- [13] 3GPP Working Group, 1xEV-DO Evaluation Methodology, Qualcomm Inc, C30-DOAH-2003, pages 47-48.